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PROTECTION AGAINST FROST ON THE OVERHEAD POWER LINES

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Abstract: *This paper investigated a method to eliminate the deposition of frost on wires of overhead lines. The method is based on the use of ferromagnetic materials with low Curie temperature incorporated in the form of conductive wires, or mounted on the conductor in the form of sleeves. A theoretical model and a computer program that allows numerical simulation of electromagnetic and thermal phenomena in the presence of frost deposition on conductors were developed.*
Key words: *overhead power lines, hoar-frost*

1. INTRODUCTION

Accumulation of ice / hoar-frost on overhead line conductors (LEA) may cause serious damage in the power system, hence the need of reducing or even eliminating them. Ice / hoar-frost in the air are dry or wet form, and accumulate in the cold wind conditions.

A typical situation is under-loading LEA (steady current value below the rated current) and an atmosphere with temperatures below 0°C, in the presence of wind, the Joule heat developed in the current conduction process leading to a temperature lower than the hoar-frost formation temperature (about -5°C).

The idea is to provide additional heating of the HV conductor, to lead to a higher temperature for the hoar-frost formation.

Additional heating is achieved by including ferromagnetic material in the structure of HV conductor. Character of conductor's self-protection is its property to revert to a temperature above the temperature of formation hoar-frost after an environmental disturbance (low temperature, wind speed increase) resulted in conductor cooling under -5°C. Such materials are materials with low Curie temperature. In Fig. 1 the saturation induction-temperature characteristics for two types of ferromagnetic materials with Curie temperatures of 830°C or 60°C are presented.

With these materials, two models for the ice / hoar-frost self protected conductors (CAP) were considered, according to the arrangement of ferromagnetic material: the insertion of filaments (CAPIN) and the outer casing (CAPMA).

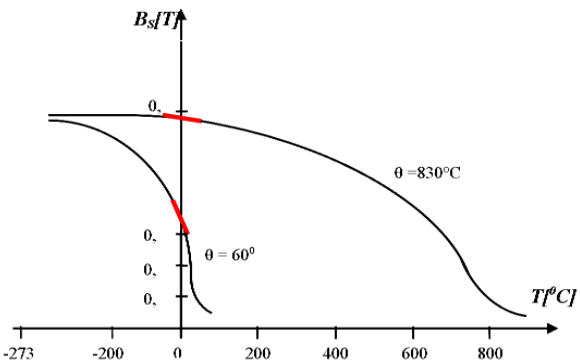

Fig. 1. Magnetic characteristic of the protective conductor material

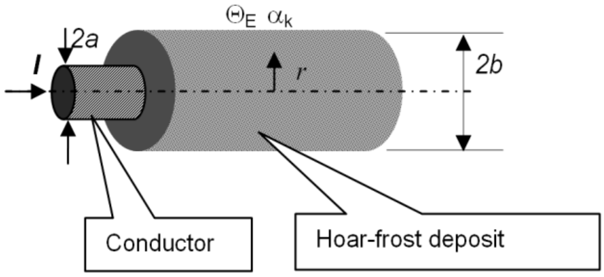

Fig. 2. Geometric configuration studied

The paper proposes a mathematical model for calculating transient thermal regime of a conductor of an overhead line, on which a deposit of frost as a cylindrical sleeve was formed.

The heat source is represented by power losses in the conductor and the power developed by self-protection elements in the form of wire or sleeves.

2 STUDIED CONFIGURATIONS

It is considered a portion of any length from a conductor on the surface which is a deposit of frost. Outside temperature is $\Theta_{E,}$ and the convection coefficient between the nozzle surface and environment is α_k

The great length of the line allows the adoption of a one-dimensional geometric pattern, in which the physical values depends only of the spatial radial coordinate (r) and time.

The frost is represented by a homogeneous medium, whose thermo-physical properties are like water properties under the two states of aggregation encountered: liquid and solid.

The state equation of the deposit presents three areas:

- At temperatures below the melting temperature (0°C), the characteristic is practically linear, with a slope equal to the specific heat of ice (or frost, if applicable).
- A vertical portion corresponding to phase transformation (melting or solidification), corresponding to the associated latent heat.
- At temperatures above the melting temperature (0°C), the characteristic is practically straight, with a slope equal to the specific heat of water.
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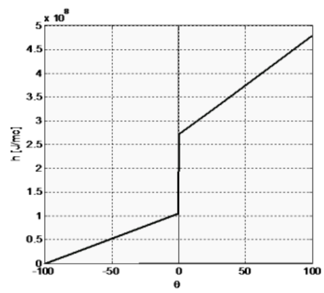

Fig.3 Equation of state of water (Enthalpy versus temperature)

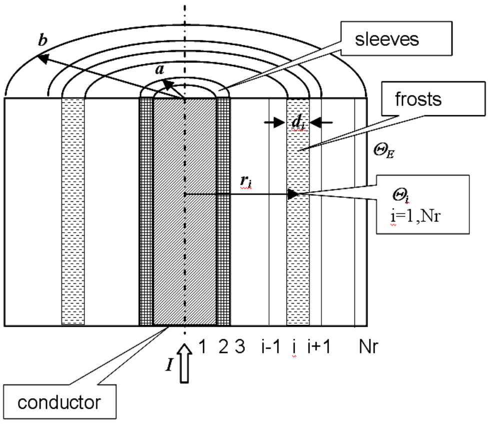

Fig.4. Configuration studied

It is difficult to estimate appropriate material properties of the hoar-frost. The hoar-frost looks like a porous medium with a density that can be significantly less than that of ice (between 90 and 300 kg/m^3), which may considerably affect the development of the phenomenon.

We suppose that the cylindrical symmetry is maintained throughout the process studied.

The problem consists in the study of the transient thermal regime represented by the conductor (metal), self-protection sleeve (in various constructive solutions) and frost coating, in contact with ambient temperature and with conditions of heat transmission.

The main difficulty consists in variations of the material properties with the temperature. The most difficult to modelize is the highly nonlinear character of the thermo-physical properties of water (or frost).

3. NUMERICAL MODEL

The studied case is a one-dimensional geometric model, with cylindrical symmetry.

Meshing elements will be N_r coaxial layers, whose thicknesses are arbitrary. The first element is the conductor, the second is the protection element (sleeve or wire), and following N_r-2 are layers of frost.

The transition phase from 0°C was divided between -0.5°C and 0.5°C, for reasons imposed by the interpolation algorithm used in MATLAB program. Between these values, the characteristic was approximated by linear interpolation, the only able to ensure the absence of parasitic oscillations. The average coefficient k_m is equal to the initial slope of the characteristic θ(h).

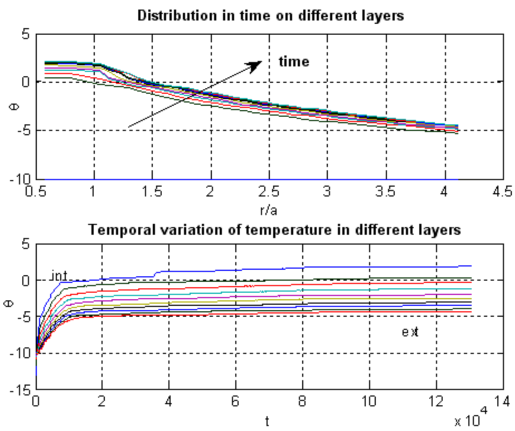

Fig. 5. In the absence of thermal protection (zero auxiliary power)

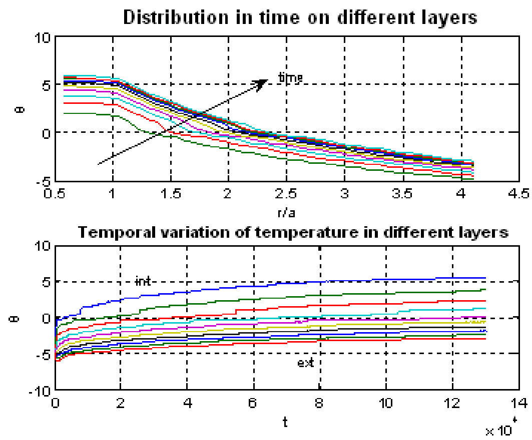

Fig. 6. With thermal protection

The presence of protective factors leads to a temperature higher of conductor than absence, thus facilitating the frost melting. It appears (fig.7) that the iteration method adopted provides an accurate representation of highly nonlinear behavior of frost (including phase change).

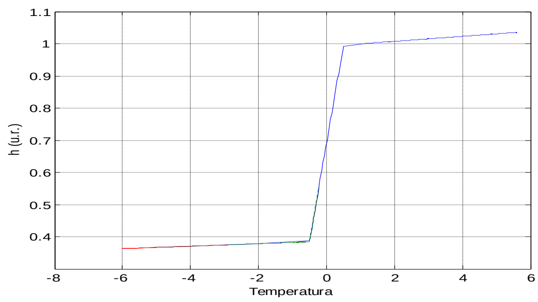

Fig. 7. Equation of state of frost (actual calculations)

4. CONCLUSION

This paper brings the following original contributions:

Modeling by similitude of physical system and experimental model of the self protection conductor, to obtain its electro-thermal parameters.

A theoretical model and a computer program for the two types of protection of conductors in different operating conditions: temperature, wind and current intensity in conductor.

Experimental investigations with different materials to highlight and analyze the practical phenomena and processes occurring on the protected conductors.

Experimental investigations were carried out at INCDIE ICPE-CA, in order to confirm the adopted calculation model.

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